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*Published in:*

Proceedings Cities of the Future: Sustainable Urban Planning and Water management.

*Publication date:*

2011

*Document Version*

Publisher's PDF, also known as Version of record

[Link back to DTU Orbit](#)

*Citation (APA):*

Zhou, Q., & Arnbjerg-Nielsen, K. (2011). A risk-based evaluation tool for feasible urban drainage design under influence of climate change. In *Proceedings Cities of the Future: Sustainable Urban Planning and Water management*. <http://www.cof2011stockholm.org/>

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# A risk-based evaluation tool for feasible urban drainage design under influence of climate change

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**Keywords:** Climate change adaptation; Flood risk assessment; socio-economic tools

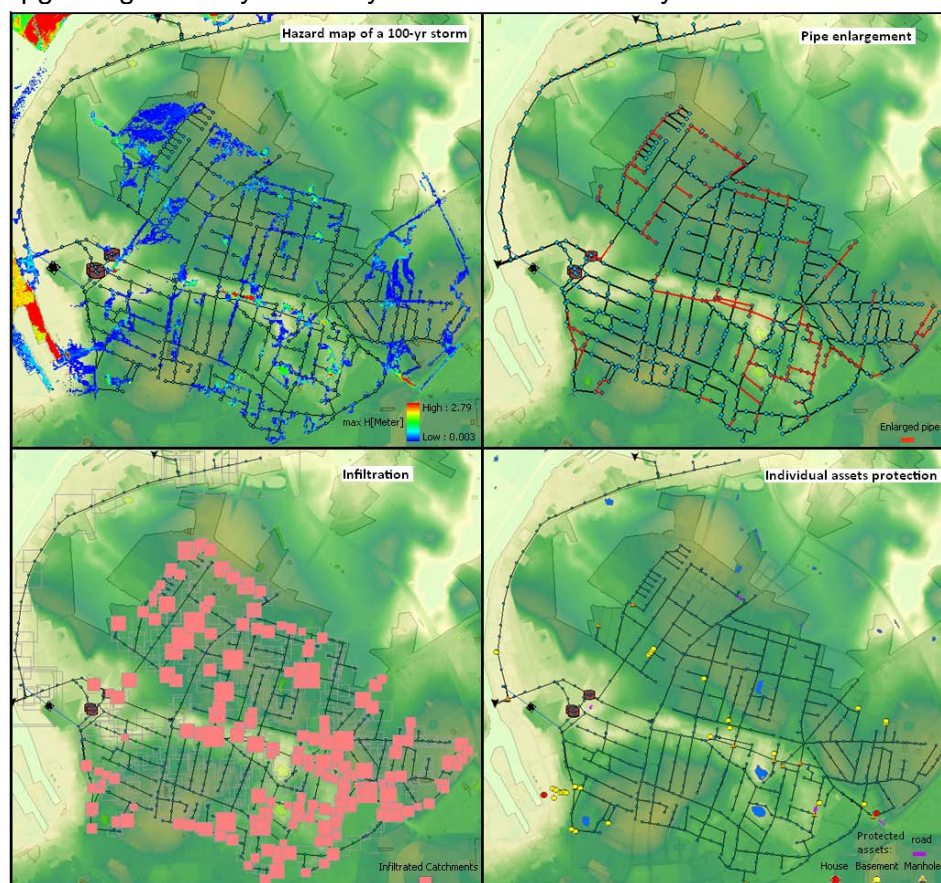
It is widely recognized that climate change is affecting precipitation extremes. In Northern Europe, many cities have already experienced an increase in frequency of flooding as a result of weather-related events; The concepts of traditional urban drainage design are being questioned and there is a growing trend towards managing urban water in a more sustainable and resilient way (Ashley et al., 2007).

Management of flood risk can be achieved through appropriate activities that alleviate the extent of hazards, reduce the probability of flooding, or mitigate the resultant damage by flooding (Burrell et al., 2007). There is a wide range of measures to change risk in different manners; they can be divided into four major types: 1) flood attenuation, i.e. to slow down and reduce the volume of surface water runoffs, such as infiltration, green roofs and flood detention; 2) flood conveyance, aimed at enhancing the conveyance capacity of excess flows, such as pipe enlargement, relief channels, etc.; 3) flood regulation and preparedness, aimed at reducing the exposure of vulnerabilities to flood hazards, i.e. individual assets protection, flood proofing, emergency services, etc.; and 4) flood defence, by using structural measures to prevent floods reaching vulnerably areas, e.g. dams, flood walls, riverbanks, etc; A better understanding of the individual performance of each type of measure is the basis for promoting the coordinated development towards sustainable transition.

This paper presents the applications of different adaptation measures in a Danish case study. A risk-based evaluation framework is developed to assess the physical and economic feasibility of the diffente measures, in order to highlight the benefits and limitations of each strategy. The framework integrates the work within the fields of flood inundation modelling, economics, risk management tools, and climate change. Three options were tested: pipe enlargement, infiltration and individual assets protection. These options correspond to a typical example of application of the first three strategies mentioned above. The fourth option is not relevant in the case study. Each option was used under two adaptation schemes: 1) overall adaptation aiming at a fixed minimum service level of any type of damage of 5 years and 2) economically optimal adaptation considers adapting to the return period that is most economically profitable. Furthermore, we think it is also advantageous for decision-maker to test if the suggested adaptation will be paid off even in the absence of climate change impacts. An example of the applied three options under the overall adaptation is illustrated in Figure 1. The calculated economic indicators (Net Present Value) of the three options proposed under the two adaptation schemes are shown in Table 1.

The assessed results indicate that infiltration has effects on water discharge and peak flow, but only to a limited extent for high return periods. Attenuation of water runoffs upstream is thus not very efficient in preventing downstream floods. Pipe enlargement was found to be efficient in solving local flood problems, in terms of both technical and economic aspects. However, due to the chain actions (back water effects) in the interconnected sewer network, the enlargement work is normally needed for a series of pipes along the overloaded manholes. Individual assets

protection is also effective in reducing the flood risk. However, this efficiency is highly dependent on local participation, which is still very limited in the urban water management. It is noteworthy that the analyzed three measures are complementary to each other; a sustainable adaptation should promote their cooperation in order to maximize the effectiveness. Furthermore, Table 1 shows that more robust and beneficial strategy could be designed under the second scheme, which indicates small upgrading of the system may be more economically feasible.



**Figure 1:** Illustration of hazards and tested adaptation options. The top left figure shows the inundated areas of a 100 year storm. The other three figures show where measures are needed to comply with a service level of no-damage corresponding to 5 years. The catchment area is a residential area in Odense, Denmark.

**Table 1:** Comparison of calculated marginal benefits of applying the three adaptation options. A discount rate of 3% has been applied.

Adaptation alternatives Descriptions	NPV [mio.DKK]			
	Adaptation with climate change		Adaptation assuming no climate change	
	Scheme 1	Scheme 2	Scheme 1	Scheme 2
1 Pipe enlargement	48.8	71.3	11.8	47.1
2 Infiltration	22.3	33.9	-19.3	20.9
3 Individual assets protection	30.7	59.4	6.0	38.7

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